Her Majesty's Consul at Mogador writes in his report: "The *akabar*, or caravan from Morocco, is the largest that crosses the desert to Timbuktu. It starts once a year, about the month of October, from Tinduf on the confines of the desert, and amounts to over 10,000 camels. Only 20 per cent. leave that station laden with goods; the others proceed to Taudeni, in the centre of the desert, where they are laden with salt for the Sudan. There are, besides, many small *akabars* which cross the desert during the year, averaging 100 camels each. The merchandise carried by these caravans consists of the following goods: blue cloth, American cloth, long cloth, sugar, tea, glass beads, amber beads, shells, and silk, from Fez and Morocco; gold, ostrich feathers, Senegal gum, gum-Arabic, frankincense, blankets, and slaves from the Sudan.

"The average value of the merchandise carried by each camel is £50. The approximate value, therefore, of the goods conveyed by the great *akabar* is £100,000; add to this sum £30,000, the value of the small caravans, and the total value of the merchandise sent yearly from Morocco to Timbuktu is £130,000. Upon this sum a profit of 75 per cent. is made by the traders, besides the gains on the salt carried from Taudeni to Timbuktu. 60 per cent. of the camels are sold at that place, as comparatively few are required for the returning with the light Sudan goods. At Timbuktu the great caravan is broken up, and the traders return in small parties to their respective homes by different routes."

The journey from Wad Nun to Timbuktu occupies twenty-eight days with dromedaries, and sixty days with ordinary camels.

The trade at Cape Juby consisted chiefly in the barter of blue and white cotton cloth, etc., for the wool yielded by the large flocks of sheep that pasture in the vicinity.

BALFOUR SHOAL:

A Submarine Elevation in the Coral Sea.

By John Murray, F.R.S., of the *Challenger* Expedition.

During the past few years Her Majesty's surveying ships have been carrying out, under the directions of Admiral Wharton, C.B., F.R.S., Hydrographer of the Admiralty, some most important surveys in the South-Western Pacific, particularly in the region lying between the latitude of New Guinea and the Solomon Islands in the north and the latitude of New Zealand in the south, extending across from the east coast of Australia eastward to beyond the Samoa, Friendly, and Kermadec groups of islands. These observations have a special interest for all who are engaged in the study of oceanographical problems.

In this region of the ocean over two thousand trustworthy soundings have now been recorded in depths exceeding 100 fathoms, nearly one-half of which have been taken in depths exceeding 1000 fathoms. These numerous deep-sea soundings have very much increased our knowledge of the bathymetrical contours of the sea-bed in this part of the ocean,

and show that the sea-bottom is very irregular; it is proposed in another paper to deal with them in detail. A feature of great interest, however, has been the development of a very deep trough, running in a north-north-east direction to the eastward of the Kermadec and Friendly Islands, which is, so far as yet known, the most depressed point on the surface of our planet. In the bathymetrical maps published in the *Challenger* Summary volumes this trough is called the Aldrich Deep, and in some German maps [1] recently published it is called the South Pacific Deep.

A sounding of 2900 fathoms taken by the *Challenger* in this locality in July 1874 indicated that the bottom lay far beneath the surface. In the summer of 1888 Captain Pelham Aldrich, in H.M.S. *Egeria*, obtained to the westward of the *Challenger* position depths of 4295 and 4428 fathoms. In the following year Commander Oldham, then in command of the *Egeria*, took a sounding in 4530 fathoms, about eight degrees farther north, which was the greatest depth known up to that time south of the equator. Six years later, on 23rd July 1895, Commander Balfour, in H.M.S. *Penguin*, in lat. 23° 39·5′ S., long. 175° 2·8′ W., made two attempts to sound, but each time the wire parted when running out, first at 4320 fathoms, and then at 4900 fathoms; a few months later in the same position he obtained a depth of 5022 fathoms. Again, on 30th December 1895, Commander Balfour sounded in 5147 fathoms, five degrees to the south of his previous sounding (in lat. 28° 44·4′ S., long. 176° 4′ W.), and on the next day, still a little farther south (in lat. 30° 27·7′ S., long. 176° 39′ W.), he obtained the deepest sounding hitherto recorded in the ocean. The depth is 5155 fathoms, or 250 yards less than six miles. In this deep trough, then, we have seven soundings in depths exceeding 4000 fathoms, three of which exceed 5000 fathoms; in what is possibly the same trough there are, in addition, twenty-eight soundings in depths between 3000 and 4000 fathoms.[2]

The numerous temperature observations taken in this region of the ocean, both in intermediate waters and at the bottom, promise, when fully worked out and discussed, results of very great interest.

Through the kindness of Admiral Wharton, I have been permitted to examine the samples of the marine deposits collected by the surveying officers in the Western Pacific. The samples brought up from the deep trough noted above are all Red Clays, and are in almost all respects identical with the deposit obtained by the *Challenger* in 2900 fathoms, consisting for the most part of very minute particles of pumice and other volcanic particles, many of them passing into palagonite. Carbonate of lime shells are wholly absent, and of siliceous organisms there are only a few broken specimens.

In this paper, however, I purpose specially to direct attention to a limited number of these soundings in a quite restricted area, and to a remarkable submarine elevation rising from the floor of the ocean, discovered by Commander Balfour while searching for the Ocean Ranger Reef. In the year 1891 the master of the barquantine *Ocean Ranger*

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[1] Deutsche Seewarte: *Stiller Ozean, ein Atlas von* 31 *Karten*. Hamburg, 1896.

[2] See Lists of Oceanic Depths received at the Admiralty (blue-books published annually).

reported to the New Zealand Government that, "on the passage from Townsville (Queensland) to Chesterfield islets, he sighted a dangerous reef (*Ocean Ranger reef*), extending 2 or 3 miles in a S.S.E. and N.N.W. direction, and on which the sea broke heavily. Observations deemed reliable place this danger in approximately lat. 18° 44′ S., long. 157° 2′ E., or with North Elbow, Bampton reefs, bearing about E. ¼ S., distant 84 miles."[1]

In August and September 1894, Commander Balfour, in H.M.S. *Penguin*, searched unsuccessfully for this danger, and it has therefore been expunged from the charts. Commander Balfour obtained, however, a considerable number of rather deep soundings in this neighbourhood, which are interesting from another point of view than that of navigation, for they develop a remarkable rising of the bottom above the general level of the sea-bed. This elevation perhaps hardly deserves the name of a "bank" or "shoal," for the shallowest depth obtained was 836 fathoms, but I have given it the name of Balfour Shoal, after its discoverer. Several of the surveying officers point out as a remarkable fact that over a submarine cone as deeply submerged as that of the Balfour Shoal there is frequently a ripple or other disturbance at the surface of the sea. This is apparently due to some massive movement of the water, of which at present we have little definite information.

The position and form of this peculiar cone-like elevation are shown on Plate I. by means of contour lines indicated by the soundings. These contour lines show rather steep slopes towards the north-east, whereas towards the south-west the slopes are more gentle. The maximum slope to the north-east is about 200 fathoms per mile, or 1 in 4·4. Although this is a rather steep submarine slope, steeper ones have been recorded,[2] for instance:—

Dacia Bank, North Atlantic, to the west of Africa,	1 in 3·1.
Seine Bank, do. do., . .	1 in 2·05.
Shoal discovered by the *Tuscarora* to the westward of San Francisco (32° 55′ N., 132° 30′ W.),	1 in 2·7.

Mr. Buchanan records a gradient of 642 fathoms per mile off the west coast of Africa (lat. 0° 26·5′ N., long. 6° 38·7′ E.), which is equal to a slope of 1 in 1·4.

The angle of the maximum slope off the Balfour Shoal is 14°, and Mr. Buchanan[3] records larger angles of slopes, as follows:—

Dacia Bank, . . .	43°
Seine Bank, . . .	23°
Off Bermuda, . . .	42°
Challenger Bank, near Bermuda, .	40°

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[1] Admiralty Notice to Mariners, No. 110, 1892.

[2] See J. Y. Buchanan, "On the Land Slopes separating Continents and Ocean Basins, especially those on the West Coast of Africa,"—*Scot. Geogr. Mag.*, vol. iii. p. 217, 1887; also G. W. Littlehales, "The Average Form of Isolated Submarine Peaks,"—U.S. Navy, Hydrographic Office, No. 95, Washington, 1890.

[3] "On Oceanic Shoals discovered in the s.s. *Dacia* in October 1883."—*Proc. Roy. Soc. Edin.*, vol. xiii. p. 440.

The Dacia Bank is precipitous in some places, and the same is the case with the "Coral Patch," situated in the same locality, which is referred to in the sequel.

The serial temperatures obtained by Commander Balfour in this part of the ocean are represented diagrammatically on Plate II., the vertical scale being to the horizontal as 1 to 22. It will be observed that the temperature at the surface ranges from 73° to 75° F., and on the summit of the shoal, in 884 fathoms, the temperature is 37·1° F. At the base of the cone, in 1758 fathoms, the bottom temperature is 35·0° F. In the deep trough to the east of the Fiji Islands the bottom temperature is in one instance recorded as low as 31·8° F.

Many submarine cones, similar to the one now under consideration, have been discovered by soundings in different regions on the floor of the ocean. In no case, however, has such a complete series of the deposits been preserved and sent home from different depths around the cone as in the work carried out in this instance by Commander Balfour. I have therefore submitted these deposits to a careful microscopical and chemical examination.

The deposits on this cone-like elevation are very different from those to which I have just referred as having been procured in the greater depths of the ocean beyond 3000 fathoms. At these great depths there is no carbonate of lime in the deposits; all the carbonate of lime organisms, which are abundant in the surface waters, are dissolved before they reach the bottom in depths of four and five miles. In the deposits on and around this Balfour Shoal, where the depths range from 836 to nearly 2000 fathoms, all the carbonate of lime organisms which flourish in the surface waters are represented in the deposits by their dead shells and skeletons.

The analyses of the samples from the Balfour Shoal show that these deposits contain a very large quantity of carbonate of lime, ranging from 88·7 per cent. on the summit to 71·9 per cent. in the deeper water at the base of the cone. The decrease in the quantity of carbonate of lime with increase of depth is not quite regular; still, a general fall in the percentage of lime is clearly indicated from shallower to deeper water. As might be expected in such a circumscribed area, there is a great uniformity both in the chemical composition and relative abundance of the organic and inorganic constituents of the deposits.

In all cases the carbonate of lime is almost wholly made up of the dead shells which have fallen from the surface waters—belonging to Plankton organisms—such as Pteropods, Heteropods, pelagic Foraminifera, coccoliths, and rhabdoliths; probably not more than 2 or 3 per cent. of the carbonate of lime in these deposits has been secreted by bottom-living organisms or animals belonging to the Benthos.[1] It is very interesting to note that in all the shallower soundings—those on the summit of the cone in depths of less than 1000 fathoms—the Pteropod and Heteropod shells are relatively abundant, and these deposits are in

[1] See Table II., showing the genera of bottom-living Foraminifera observed in these deposits, p. 126.

consequence called PTEROPOD OOZES. In the map (Plate I.) the summit of the bank covered by Pteropod Ooze is indicated by a distinctive colour, the slopes and deep water around the bank covered by Globigerina Ooze being indicated in shades of blue. In these same deposits the thin delicate species of pelagic Foraminifera, such as *Globigerina digitata*, *Hastigerina pelagica*, and *Candeina nitida*, are likewise present, while they, as well as the Pteropod and Heteropod shells, disappear almost completely from the deposits procured from the greater depths beyond 1500 fathoms. With the disappearance of these thin and more delicate pelagic shells from the deposits, there is a corresponding diminution in the percentage of carbonate of lime in the greater depths. Had the depths immediately surrounding the Balfour Shoal reached 3000 or 4000 fathoms, the whole of these pelagic carbonate of lime shells would have disappeared from the deposits, and we should then have had a Red Clay similar to that procured from the Aldrich Deep to the east of the Kermadec and Friendly Islands.

In depths beyond 1000 fathoms around the Balfour Shoal, the deposits are typical GLOBIGERINA OOZES. The most abundant species are *Orbulina universa*, *Globigerina bulloides*, *Globigerina conglobata*, *Pullenia obliquiloculata*, and *Pulvinulina menardii*; indeed, I estimate that these five species and their broken down parts make up fully 50 per cent. of the whole deposit.[1] In all these deposits—both the Pteropod and Globigerina Oozes—the calcareous shells were in very many cases discoloured brown or black by depositions of the peroxide of manganese; the *Globigerina* shells were often covered with little black grains of this substance, which gave them a mottled, and sometimes even a jet-black, appearance.

After the removal of the carbonate of lime from the deposits by dilute hydrochloric acid, the residue was found to consist for the most part of minute fragments of pumice. These ranged from macroscopic fragments 4 to 5 mm. in diameter down to the most minute splinters. Small fragments of palagonite and grains of manganese peroxide were also present. In some cases there were minute rounded fragments of quartz, covered with a red oxide of iron. These quartz particles are similar in all respects to those found in the Atlantic, which are believed to have been borne by wind from the Sahara; probably they came in like manner from the deserts of Australia.

In the residue there were always a few siliceous organisms, such as spicules of Sponges, Radiolaria, and a few Diatoms; it is estimated that these make up from 2 to 3 per cent. of the deposits. In some cases there were a few brown-coloured casts of the Foraminifera in the residue, but these were not nearly so abundant as in some samples of Globigerina Ooze procured by the *Challenger* in the same region and at about the same depth—for instance, between the Fijis and New Hebrides.[2]

On the north-east steep side of the Balfour Shoal there were indications that depositions of manganese peroxide were more abundant than

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[1] See Table I., showing the relative abundance of the species of pelagic Foraminifera, p. 125.

[2] See *Challenger* Report on *Deep-Sea Deposits*, page 176.

TABLE I.

SHOWING THE RELATIVE ABUNDANCE OF THE SPECIES OF PELAGIC FORAMINIFERA IN THE VARIOUS DEPOSITS.

	I. 836 fms.	II. 974 fms.	III. 1000 fms.	IV. 1060 fms.	V. 1163 fms.	VI. 1186 fms.	VII. 1192 fms.	VIII. 1227 fms.	IX. 1343 fms.	X. 1402 fms.	XI. 1515 fms.	XII. 1552 fms.	XIII. 1568 fms.	XIV. 1642 fms.	XV. 1740 fms.	XVI. 1758 fms.	XVII. 1798 fms.	XVIII. 1845 fms.	XIX. 1965 fms.
1. *Orbulina universa*,	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.
2. *Globigerina bulloides*,	v.m.	v.m.	v.m.	m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.
3. ,, *rubra*,	m.	f.	m.	f.	f.	m.	f.	m.	m.	f.	f.	f.	f.	m.	f.	m.	m.	m.	f.
4. ,, *conglobata*,	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.
5. ,, *dubia*,	v.m.	m.	v.m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	v.m.	m.
6. ,, *inflata*,	f.	m.	m.	f.	m.	f.	f.	f.	f.	f.	v.f.	f.	f.	f.	m,	f.	v.m.	f.	v.f.
7. ,, *sacculifera*,	m.	m.	m.	m.	m.	m.	m.	m.	m.	f.	m.	m.	m.	m.	m.	m.	m.	m.	m.
8. ,, *digitata*,	...	...	...	v.f.	v.f.	...	...	v.f.	v.f.	v.f.	v.f.	v.f.	v.f.	v.f.	...	v.f.	v.f.	v.f.	v.f.
9. ,, *æquilateralis*,	m.	f.	m.	m.	m.	m.	m.	f.	m.	f.	f.	m.	f.	f.	m.	m.	f.	f.	f.
10. *Hastigerina pelagica*,	v.f.	...	...	...	...	v.f.	...	v.f.	v.f.	...	...	v.f.	...	...	...	...	...	...	...
11. *Candeina nitida*,	f.	f.	f.	f.	v.f.	f.	f.	v.f.	v.f.	f.	v.f.	v.f.	v.f.	v.f.	v.f.	v.f.	v.f.	v.f.	...
12. *Sphæroidina dehiscens*,	m.	m.	f.	m.	m.	f.	f.	f.	f.	f.	f.	m.	f.	f.	m.	m.	m.	f.	m.
13. *Pullenia obliquiloculata*,	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.
14. *Pulvinulina menardii*,	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	v.m.	f.	v.m.	v.m.	v.m.	v.m.
15. ,, *tumida*,	m.	m.	m.	v.m.	f.	f.	f.	f.	f.	f.	f.	f.	f.	f.	v.f.	f.	f.	f.	m.
16. ,, *canariensis*,	v.m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	v.m.	m.	m.	m.	m.
17. ,, *crassa*,	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	v.m.	m.	m.	m.	m.
18. ,, *micheliniana*,	v.m.	v.m.	v.m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	v.m.	m.	m.

v.m. = very many. m. = many. f. = few. v.f. = very few.

TABLE II.

SHOWING THE GENERA OF BOTTOM-LIVING FORAMINIFERA OBSERVED IN THE VARIOUS DEPOSITS.

	I. 836 fms.	II. 974 fms.	III. 1000 fms.	IV. 1060 fms.	V. 1163 fms.	VI. 1186 fms.	VII. 1192 fms.	VIII. 1227 fms.	IX. 1343 fms.	X. 1402 fms.	XI. 1515 fms.	XII. 1552 fms.	XIII. 1568 fms.	XIV. 1642 fms.	XV. 1740 fms.	XVI. 1758 fms.	XVII. 1798 fms.	XVIII. 1845 fms.	XIX. 1965 fms.
Biloculina,	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Spiroloculina,	*	...	...	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...
Miliolina,	*	*	*	*	*	*	*	*	*	*	*	*	*	...	*	...	...	*	*
Textularia,	*	*	*	*	*	*	*	*	*	*	...	*	*	*	*	...	...	*	...
Verneuilina,	...	...	...	...	*	*	*	...	*	...	...	...	...	...	...	...	...	...	...
Gaudryina,	*	...	...	*	...	*	*	...	*	...	...	...	*	...	...	...	...	...	...
Bulimina,	*	...	*	...	...	...	...	*	...	...	...	...	...	...	...	...	...	*	...
Bolivina,	*	...	...	*	...	...	...	...	...	..	..	...	...	...	..	...	*	...	...
Cassidulina,	*	*	*	...	*	*	*	*	*	*	...	*	*	*	...	...	...	*	*
Ehrenbergina,	...	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Lagena,	*	*	*	*	*	*	*	*	...	*	...	*	*	*	*	...	*	*	*
Nodosaria,	*	...	...	*	..	*	*	...	*	...	*	...	*	...	*	...	*	..	...
Cristellaria,	...	...	*	...	...	...	...	...	...	...	...	...	...	..	...	...	..	...	...
Polymorphina,	*	...	...	*	..	*	*	*	...	*	...	*	...	*	...	...	*	...	...
Uvigerina,	*	*	*	*	...	...	*	...	*	*	...	*	*	*	...	...	*	...	...
Pullenia quinqueloba,	*	...	...	...	...	...	...	*	...	*	...	*	...	*	...	...	...	...	...
,, *sphæroides*,	*	*	*	..	*	*	...	*	...	*	*	...	...	*	...	...	...	...	...
Sphæroidina bulloides,	...	...	...	...	...	...	...	...	*	...	...	...	...	...	...	...	*	...	...
Truncatulina,	*	*	*	*	*	*	*	*	*	*	...	*	*	...	*	*	*	*	*
Pulvinulina elegans,	*	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..	...
,, *exigua*,	...	*	...	...	...	...	...	...	...	...	...	...	*	...	...	..	...	...	...
,, *favus*,	...	...	...	...	...	*	...	...	...	*	*	...	...	*	...	*	...	...	...
,, *pauperata*,	...	*	...	...	...	*	*	...	*	*	...	...	*	...	*	...	...	...	...
Rotalia,	*	*	...	*	*	*	*	...	...	...	..	*	*	...	*	*	*	*	*
Nonionina,	*	...	...	...	*	...	*	...	*	*	*	*	*	*	*	...	*	*	*
Polystomella,	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	..	*	...	...

These bottom-living forms are all rare; often only a single representative was observed in the large quantity of material examined, and very seldom more than half-a-dozen examples. The species are given for those genera which contain pelagic representatives.

elsewhere. In 1549 fathoms several small pieces of a very fine-grained tuff covered with manganese peroxide were procured. Again, in 1645 fathoms, there was an angular fragment of a mottled yellowish jasper coated with manganese peroxide, and in 1570 fathoms there were three characteristic spherical black manganese nodules from one-half to three-fourths of an inch in diameter, quite similar to those procured by the *Challenger* in many areas of the Pacific and Atlantic. In one of these nodules the nucleus was a sub-angular fragment of a light-coloured augite-granophyre (see pages 132 and 133).

We are now acquainted with many instances of manganese peroxide occurring in the deposits about the steep slopes of oceanic islands, whether these be composed of coral or of volcanic material,—for instance off Christmas Island in the Indian Ocean, off Teneriffe, and other islands. Mr. Buchanan mentions a bank or "Coral Patch" in the Eastern Atlantic, on which the depth was 435 fathoms. On the western side the bank seemed to fall away precipitously from 550 to 835 fathoms; in one sounding on this ledge the sinker distinctly struck bottom in 550 fathoms, then tumbled over and continued to sink, struck in 620 fathoms, and again tumbled over, and finally found a resting-place in 835 fathoms. When hauled up the sinker had a large blackish-brown streak on it, having evidently struck obliquely on masses of manganese peroxide.[1] It seems evident that on the steep slopes of these oceanic islands large surfaces of volcanic rock are exposed to the action of sea-water, and are slowly decomposed and altered. The manganese which is deposited in the form of peroxide on the shells and other objects in the neighbourhood of such a cone was doubtless originally derived from the decomposition of the volcanic materials, which in the first instance formed this conical elevation on the sea-bed.[2]

In my papers on the Structure and Origin of Coral Reefs and Islands,[3] I have pointed out that volcanic mountains rise from the sea-floor to varying heights; some of them rise above the surface of the ocean and appear as islands, while others which may at one time have appeared as islands have been reduced by wave action to a depth of several fathoms beneath the surface of the sea. Again, the tops of others may be deeply submerged, for instance, like the "Coral Patch" in the Atlantic, 435 fathoms, or like the Balfour Shoal, 836 fathoms, beneath the surface. These latter, I have maintained, might in process of time be built up to the surface by depositions of pelagic shells on the summit, and by the accumulation of the remains of Benthos organisms; so that ultimately they might form the base on which true coral atolls might be formed by the agency of reef-forming species. From the examination of the samples from the Balfour Bank or Shoal, it is evident that the deposits on the summit are growing at a more rapid rate than those on the slopes, but we have no definite notion as to the rate of that increase. In the samples from the summit of the Balfour Shoal we have no indications

[1] Buchanan, *Proc. Roy. Soc. Edin.*, vol. xiii. p. 431.

[2] See Murray and Irvine "On the Manganese Oxides and Manganese Nodules in Marine Deposits."—*Trans. Roy. Soc. Edin.*, vol. xxxvii. p. 736, 1894.

[3] *Proc. Roy. Soc. Edin.*, vol. x. p. 505, 1880; *Proc. Roy. Institution*, March 16, 1888.

of any abundant growth of Benthos species, though there have been as yet no dredgings thereon; but on the Coral Patch, in 530 fathoms, Mr. Buchanan obtained a very large quantity of growing Coral—*Lophohelia prolifera*—and several specimens of Comatula—*Antedon*. It is to be hoped that, when opportunity again occurs, other surveyors will follow Commander Balfour's example, and make a careful collection of the deposits on the summit and slopes of these submarine cones, for we still require much information about the changes which are taking place in such situations, and of the variations in the composition of the deposits with varying depth.

Descriptions of the Deposits on and around the Balfour Shoal.

The plan adopted in the examination and description of the deposit samples collected by the *Challenger*[1] has been followed in dealing with the deposits from the neighbourhood of the Balfour Shoal. Each sample was divided into two portions, one of which was washed and prepared for microscopic examination, after the macroscopic characters had been noted, the other being used for the quantitative determination of the percentage of carbonate of lime.

In the descriptions the particulars as to date, position, and depth are first given. The name of the deposit follows in dark type, thus: **Globigerina Ooze**, with an indication of the colour and other macroscopic characters. Under the heading Calcium Carbonate, in small capitals, are given (1) the percentage of carbonate of lime as determined by chemical analysis in parentheses; and (2) the different kinds of calcareous organisms arranged usually in the order of their relative abundance. The Residue is the complement of the Calcium Carbonate, and the percentage is given in parentheses, followed by an indication of the colour. The Residue was divided by decantation into three portions, viz., (1) *Minerals*, (2) *Siliceous Organisms*, and (3) *Fine Washings*, the percentage of each of which was estimated by inspection. These estimated percentages are inserted in the descriptions within square brackets, to distinguish them from the figures given for the percentages of Calcium Carbonate and of Residue, which are the result of quantitative determinations. Under the heading *Minerals*, following the estimated percentage, the average size of the mineral particles in millimetres is occasionally indicated thus: m.di. 0·06 mm.; the mineral species observed are then enumerated in the order of their relative abundance. Under the heading *Siliceous Organisms*, following the estimated percentage, the remains of silica-secreting organisms (such as Diatoms and Radiolarians) are mentioned in the order of relative abundance. The Fine Washings include all the finest non-calcareous particles of the deposit, which pass off with the first decantations, and consist principally of amorphous clayey matter coloured by the oxides of manganese and iron, but contain also minute indeterminable fragments of minerals and siliceous organisms, as indicated under the heading *Fine Washings*, following the estimated percentage.

H.M.S. PENGUIN.

Sounding 87, 12th August 1894, lat. 18° 56·2′ S., long. 156° 57·8′ E., 836 fathoms.

Pteropod Ooze, of a fawn colour. This sounding appears to represent the summit of the bank.

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[1] See *Challenger* Report on *Deep-Sea Deposits*, 1891.

Calcium Carbonate (88·7%), many Pteropods, mostly in a fragmentary condition, only the small shells being approximately perfect, many small Lamellibranch and Gasteropod shells, a few Heteropod shells, pelagic and bottom-living Foraminifera, Ostracodes, Echini spines, otoliths, coccoliths, rhabdoliths, a few spherical crystalline aggregations. Some of the shells discoloured (brown or black) by manganese.

Residue (11·3%), brown.

Minerals [1%], a few pumice fragments and small black spherules (manganese ?).

Siliceous Organisms [2%], Sponge spicules, Radiolaria, and fragmentary arenaceous Foraminifera.

Fine Washings [8·3%], amorphous clayey matter and minute mineral particles.

Sounding 88, 12th August 1894, lat. 19° 3·3′ S., long. 156° 56·5′ E., 974 fathoms.

Globigerina Ooze, of a fawn colour.

Calcium Carbonate (87·6%), pelagic and bottom-living Foraminifera, a few shells and fragments of Pteropods, Heteropods, Cirripeds and Gasteropods, Echini spines, Ostracodes, otoliths and teeth of fishes, coccoliths, rhabdoliths (numerous), one or two small spherical crystalline aggregations. Some of the Foraminiferous shells discoloured by manganese.

Residue (12·4%), brown.

Minerals [1%], a few minute pumice and glassy particles, fragment of volcanic glass (1 mm. in diameter) with imbedded crystals of felspar.

Siliceous Organisms [3%], Sponge spicules, Radiolaria, Diatoms, fragments of arenaceous Foraminifera, one or two imperfect casts.

Fine Washings [8·4%], amorphous clayey matter and minute mineral particles.

Sounding 94, 12th August 1894, lat. 18° 52·1′ S., long. 156° 41·7′ E., 1000 fathoms.

Pteropod Ooze, of a fawn colour.

Calcium Carbonate (86·4%), pelagic and bottom-living Foraminifera, shells and fragments of Pteropods, Heteropods, Gasteropods and Lamellibranchs. Ostracodes, Echini spines, otoliths, coccoliths, rhabdoliths, spherical crystalline aggregations. Many of the shells, etc., are discoloured by manganese, some being uniformly brown, others with brown or black spots, and one small shell of *Globigerina bulloides* is jet black.

Residue (13·6%), brown.

Minerals [2%], pumice, mostly in small fragments, though two or three pieces 1 to 2 mm. in diameter were observed.

Siliceous Organisms [3%], Sponge spicules, Radiolaria, Diatoms, arenaceous Foraminifera, imperfect casts.

Fine Washings [8·6%], amorphous clayey matter with minute splinters of pumice.

Sounding 162, 21st November 1895, lat. 18° 11·5′ S., long. 155° 34·7′ E., 1060 fathoms.

Globigerina Ooze, fawn colour, granular.

Calcium Carbonate (79·5%), pelagic and bottom-living Foraminifera, fragments of Pteropods, Heteropods, Lamellibranchs, Gasteropods and Polyzoa,

Ostracodes, otoliths, Echini spines, coccoliths, rhabdoliths, crystalline aggregations.

Residue (20·5%), brown.

Minerals [3%], pumice, manganese grains, palagonite, quartz (an angular crystal 0·8 mm. in diameter observed); there is a fragment of soft weathered rock, dark red-brown in colour, 5 mm. in diameter.

Siliceous Organisms [2%], Radiolaria, Sponge spicules, fragments of arenaceous Foraminifera.

Fine Washings [15·5 %], amorphous clayey matter and minute mineral particles.

Sounding 95, 13th August 1894, lat. 18° 52′ S., long. 156° 33·5′ E., 1163 fathoms.

Globigerina Ooze, of a fawn colour, granular.

Calcium Carbonate (88·7%), pelagic and bottom-living Foraminifera, Ostracodes, Echini spines, otoliths and teeth of fishes, coccoliths, rhabdoliths.

Residue (11·3%), brown.

Minerals [1%], pumice, quartz (angular crystal 0·5 mm. in diameter, and a few small rounded grains covered with ologist), manganese grains, glassy particles.

Siliceous Organisms [2%], Sponge spicules, Radiolaria, Diatoms, arenaceous Foraminifera.

Fine Washings [8·3%], amorphous clayey matter and minute mineral particles.

Sounding 93, 12th August 1894, lat. 18° 59·5′ S., long. 156° 43·3′ E., 1186 fathoms.

Globigerina Ooze, of a fawn colour, granular.

Calcium Carbonate (84·9%), pelagic and bottom-living Foraminifera, fragments of Pteropods and Heteropods, Echini spines, Ostracodes, otoliths, Cirriped fragments, coccoliths, rhabdoliths.

Residue (15·1%), brown.

Minerals [2%], pumice (one fragment 3 mm. in diameter observed), glassy particles, palagonite, quartz (small rounded grains covered with ologist). Most of the mineral particles are less than 0·05 mm. in diameter.

Siliceous Organisms [3%], Sponge spicules, Radiolaria, arenaceous Foraminifera.

Fine Washings [10·1%], amorphous clayey matter and minute mineral particles.

Sounding 89, 12th August 1894, lat. 19° 10·2′ S., long. 156° 54·9′ E., 1192 fathoms.

Globigerina Ooze, fawn.

Calcium Carbonate (85·5%), pelagic and bottom-living Foraminifera, Pteropod fragments, Ostracodes, Echini spines, otoliths and teeth of fishes, coccoliths, rhabdoliths.

Residue (14·5%), brown.

Minerals [2%], pumice (one or two pieces 5 to 7 mm. in diameter), magnetite, glassy particles, palagonite, quartz.

Siliceous Organisms [3%], Sponge spicules, arenaceous Foraminifera, Radiolaria.

Fine Washings [9·5%], amorphous clayey matter and minute mineral particles.

Sounding 91, 12th August 1894, lat. 19° 6·1′ S., long. 156° 49·9′ E., 1227 fathoms.

Globigerina Ooze, of a fawn colour.

Calcium Carbonate (82·0%), pelagic and bottom-living Foraminifera, Ostracodes, Echini spines, otoliths and teeth of fishes, one or two fragments of Pteropods, Heteropods, and Lamellibranchs, coccoliths, rhabdoliths.

Residue (18·0%), brown.

Minerals [2%], principally pumice, glassy particles, palagonite, quartz.

Siliceous Organisms [4%], Sponge spicules, Radiolaria, arenaceous Foraminifera, Diatoms, imperfect casts.

Fine Washings [12%], amorphous clayey matter and minute mineral particles.

Sounding 90, 12th August 1894, lat. 19° 11·5′ S., long. 156° 49·1′ E., 1343 fathoms.

Globigerina Ooze, of a fawn colour.

Calcium Carbonate (85·5%), pelagic and bottom-living Foraminifera, Echini spines, Ostracodes, otoliths, one or two Heteropod fragments, coccoliths, rhabdoliths ; a few of the shells discoloured by manganese.

Residue (14·5%), brown.

Minerals [2%], pumice, glassy particles, palagonite, small rounded quartz grains covered with ologist.

Siliceous Organisms [3%], Sponge spicules, Radiolaria, arenaceous Foraminifera, imperfect casts.

Fine Washings [9·5%], amorphous clayey matter and minute mineral particles.

Sounding 102, 14th August 1894, lat. 18° 42·3′ S., long. 156° 42·5′ E., 1402 fathoms.

Globigerina Ooze, fawn colour.

Calcium Carbonate (83·4%), pelagic and bottom-living Foraminifera, one or two fragments of Pteropods and Heteropods, Echini spines, Ostracodes, otoliths and teeth of fishes, coccoliths, rhabdoliths (numerous). Some of the Foraminifera shells are discoloured (brown or black) by manganese.

Residue (16·6%), brown.

Minerals [1%], pumice (one fragment 1 mm. in diameter observed), but nearly all the mineral particles are less than 0·05 mm. in diameter.

Siliceous Organisms [5%], Sponge spicules, Radiolaria, and arenaceous Foraminifera fragments.

Fine Washings [10·6%], amorphous clayey matter and minute mineral particles.

Sounding 124, 8th September 1894, lat. 18° 45′ 36″ S., long. 157° 35′ E., 1515 fathoms.

Globigerina Ooze, of a pale fawn colour.

Calcium Carbonate (79·7%), pelagic and bottom-living Foraminifera, Ostracodes, Echini spines, otoliths and teeth of fishes ; one Heteropod shell observed.

Residue (20·3%), brown.

Minerals [3%], pumice (one piece 4 mm. in diameter observed), volcanic glass, quartz.

Siliceous Organisms [4/], Sponge spicules, Radiolaria, Diatoms, fragments of arenaceous Foraminifera, imperfect casts.

Fine Washings [13·3%], amorphous clayey matter and minute mineral particles.

Sounding 99, 13th August 1894, lat. 18° 44·8′ S., long. 156° 59·6′ E., 1549 fathoms.

The sounding tube brought up a few small pieces of tufa, soft and of a dirty yellow colour, coated more or less with oxide of manganese.

Sounding 113, 16th August 1894, lat. 19° 50·8′ S., long. 156° 54·6′ E., 1552 fathoms.

Globigerina Ooze, fawn colour, granular, with macroscopic pieces of pumice (the largest 4 mm. in diameter).

Calcium Carbonate (79·4%), pelagic and bottom-living Foraminifera (with a good many young forms), one or two Pteropod fragments, Echini spines, Ostracodes, Alcyonarian spicules, otoliths (one very large, corroded, and coated with manganese), coccoliths, rhabdoliths (numerous).

Residue (20·6%), brown.

Minerals [2%], m.di. 0·06 mm., pumice, rounded grains of quartz covered with ologist, glassy and coloured particles. Except the pieces of pumice, nearly all the mineral particles are less than 0·05 mm. in diameter.

Siliceous Organisms [4%], Sponge spicules, Radiolaria, Diatoms, arenaceous Foraminifera.

Fine Washings [14·6%], amorphous clayey matter and minute minerals.

Sounding 78, 10th August 1894, lat. 19° 33·3′ S., long. 156° 26·9′ E., 1568 fathoms.

Globigerina Ooze, fawn.

Calcium Carbonate (83·4%), pelagic and bottom-living Foraminifera, Ostracodes, Echini spines, otoliths and teeth of fishes, single Heteropod fragment seen ; coccoliths, rhabdoliths.

Residue (16·6%) brown.

Minerals [2%], pumice, magnetite, glassy particles, palagonite, small rounded quartz grains covered with ologist.

Siliceous Organisms [2%], Sponge spicules, Radiolaria, arenaceous Foraminifera, Diatoms.

Fine Washings [12·6%], amorphous clayey matter and minute mineral particles.

Sounding 109, 15th August 1894, lat. 18° 53·5′ S., long. 157° 6·9′ E., 1570 fathoms.

The sounding tube brought up three characteristic spherical black manganese nodules, the largest of which is thus described by Mr. Teall of the Geological Survey :—"The largest nodule measures about three-quarters by half an inch. The crust of manganese oxide is about one-eighth of an inch in thickness. The nucleus is a sub-angular fragment of a light coloured augite-granophyre. Under the microscope the rock is seen to be composed of more or less idiomorphic crystals of plagioclase and grains of a green pyroxene in a micro-pegmatitic matrix of quartz and felspar. A few grains of iron-ore are also present. Similar rocks occur amongst the granophyres of the Inner Hebrides."

Sounding 101, 14th August 1894, lat. 18° 33·3′ S., long. 156° 39·5′ E., 1642 fathoms.

Globigerina Ooze, of a fawn colour.

Calcium Carbonate (81·2%), pelagic and bottom-living Foraminifera, Echini spines, Ostracodes, teeth of fishes, fragments of Heteropods, coccoliths, rhabdoliths.

Residue (18·8%), brown.

Minerals [2%], pumice (two pieces about 3 mm. in diameter observed with projecting crystals of felspar, etc.), glassy particles, quartz (some small rounded grains covered with ologist), palagonite, manganese grains. Except the pumice, the mineral particles are nearly all less than 0·05 mm. in diameter.

Siliceous Organisms [4%], Sponge spicules, Radiolaria, Diatoms, fragments of arenaceous Foraminifera.

Fine Washings [12·8%], amorphous clayey matter and minute mineral particles.

Sounding 106, 14th August 1894, lat. 18° 49·5′ S., long. 157° 12·6′ E., 1645 fathoms.

The sounding tube brought up a piece of rock covered with manganese, which is thus described by Mr. Teall :—"Angular fragment of a mottled yellowish jasper coated with a thin crust of manganese oxide. The rock is formed of cryptocrystalline and microcrystalline quartz. The cryptocrystalline portions are stained yellow and occur in irregular patches ; the microcrystalline portions form veins and are comparatively free from colouring matter. Traces of the concentric deposition of silica may be seen, but re-crystallisation appears to have taken place."

Sounding 77, 9th August 1894, lat. 20° 10′ S., long. 156° 3·9′ E., 1740 fathoms.

Globigerina Ooze, fawn (creamy white when dry).

Calcium Carbonate (72·0%), pelagic and bottom-living Foraminifera, Echini spines, Ostracodes, teeth of fishes, one or two fragments of Pteropods and Heteropods, coccoliths, rhabdoliths.

Residue (28·0%), light brown.

Minerals [1%], pumice (one piece 4 mm. in diameter observed), magnetite glassy particles.

Siliceous Organisms [2%], Sponge spicules, Radiolaria, arenaceous Foraminifera.

Fine Washings [25%], amorphous clayey matter with a few minute mineral particles.

Sounding 80, 11th August 1894, lat. 18° 35·1′ S., long. 157° 10·5′ E., 1758 fathoms.

Globigerina Ooze, fawn.

Calcium Carbonate (79·4%), pelagic and bottom-living Foraminifera, Echini spines, Ostracodes, teeth of fishes, single fragment of Pteropod seen, coccoliths, rhabdoliths.

Residue (20·6%), brown.

Minerals [2%], pumice (one piece 4 mm. in diameter observed), volcanic glass, magnetite, quartz.

Siliceous Organisms [3%], Sponge spicules, Radiolaria, fragments of arenaceous Foraminifera, Diatoms.

Fine Washings [15·6%], amorphous clayey matter and minute mineral particles.

Sounding 83, 11th August 1894, lat. 18° 35·4′ S., long. 156° 59·4′ E., 1798 fathoms.

Globigerina Ooze, dirty white when dry, grey when wet; fine-grained.

Calcium Carbonate (84·5%), pelagic and bottom-living Foraminifera (the shells are nearly all of small size, with a very large proportion of young ones, and many of them are coloured brown by manganese or with black spots), a very few Pteropod fragments, Ostracodes, Echini spines, otoliths and teeth of fishes, Polyzoa, coccoliths, rhabdoliths.

Residue (15·5%), chocolate colour.

Minerals [3%], pumice, quartz (sometimes coated with ologist), manganese grains, palagonite, glassy particles; an angular crystal (quartz or felspar) 0·4 mm. in diameter was observed.

Siliceous Organisms [4%], Sponge spicules, brown casts.

Fine Washings [8·5%], amorphous clayey matter with oxides of manganese and iron.

Sounding 126, 8th September 1894, lat. 17° 59′ 6″ S., long. 157° 30′ 25″ E., 1845 fathoms.

Globigerina Ooze, of a fawn colour.

Calcium Carbonate (71·9%), pelagic and bottom-living Foraminifera, teeth of fishes, single Pteropod fragment noticed, coccoliths, rhabdoliths.

Residue (28·1%), brown.

Minerals [3%], principally pumice (one piece 6 mm. in diameter observed), volcanic glass, palagonite, olivine, quartz.

Siliceous Organisms [4%], Sponge spicules, Radiolaria (including Challengeridæ), Diatoms, arenaceous Foraminifera, imperfect casts.

Fine Washings [21·1%], amorphous clayey matter and minute mineral particles.

Sounding 125, 8th September 1894, lat. 18° 21′ 59″ S., long. 157° 58′ E., 1965 fathoms.

Globigerina Ooze, of a fawn colour.

Calcium Carbonate (73·6%), pelagic and bottom-living Foraminifera, Echini spines, otoliths, single Pteropod fragment observed, coccoliths, rhabdoliths.

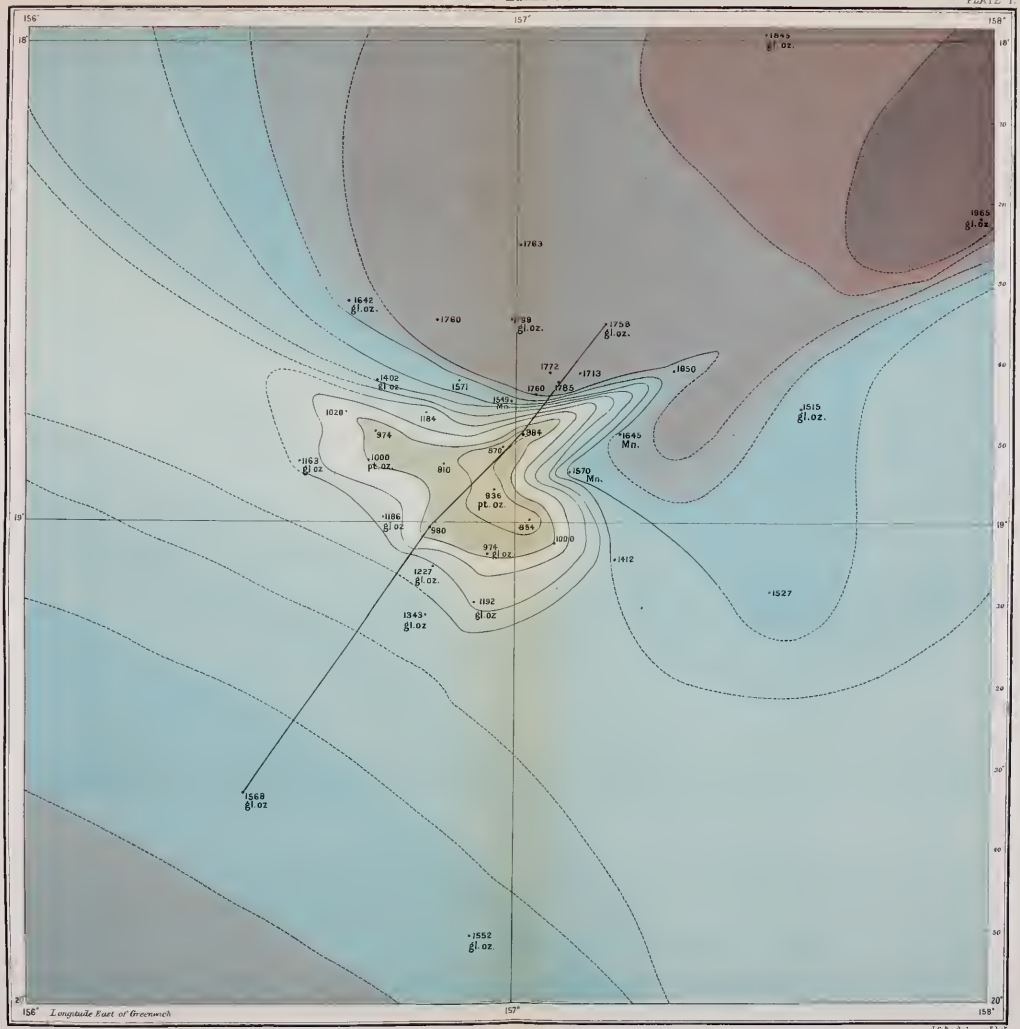
Residue (26·4%), brown.

Minerals [3%], pumice (one fresh piece 2 mm. in diameter noticed, while another piece 4 mm. in diameter was much altered and fell to powder between the fingers), felspar, magnetite (one fragment 2 mm. in diameter), palagonite, quartz (sometimes covered with ologist).

Siliceous Organisms [4%,] Sponge spicules, Radiolaria (including Challengeridæ), Diatoms, arenaceous Foraminifera.

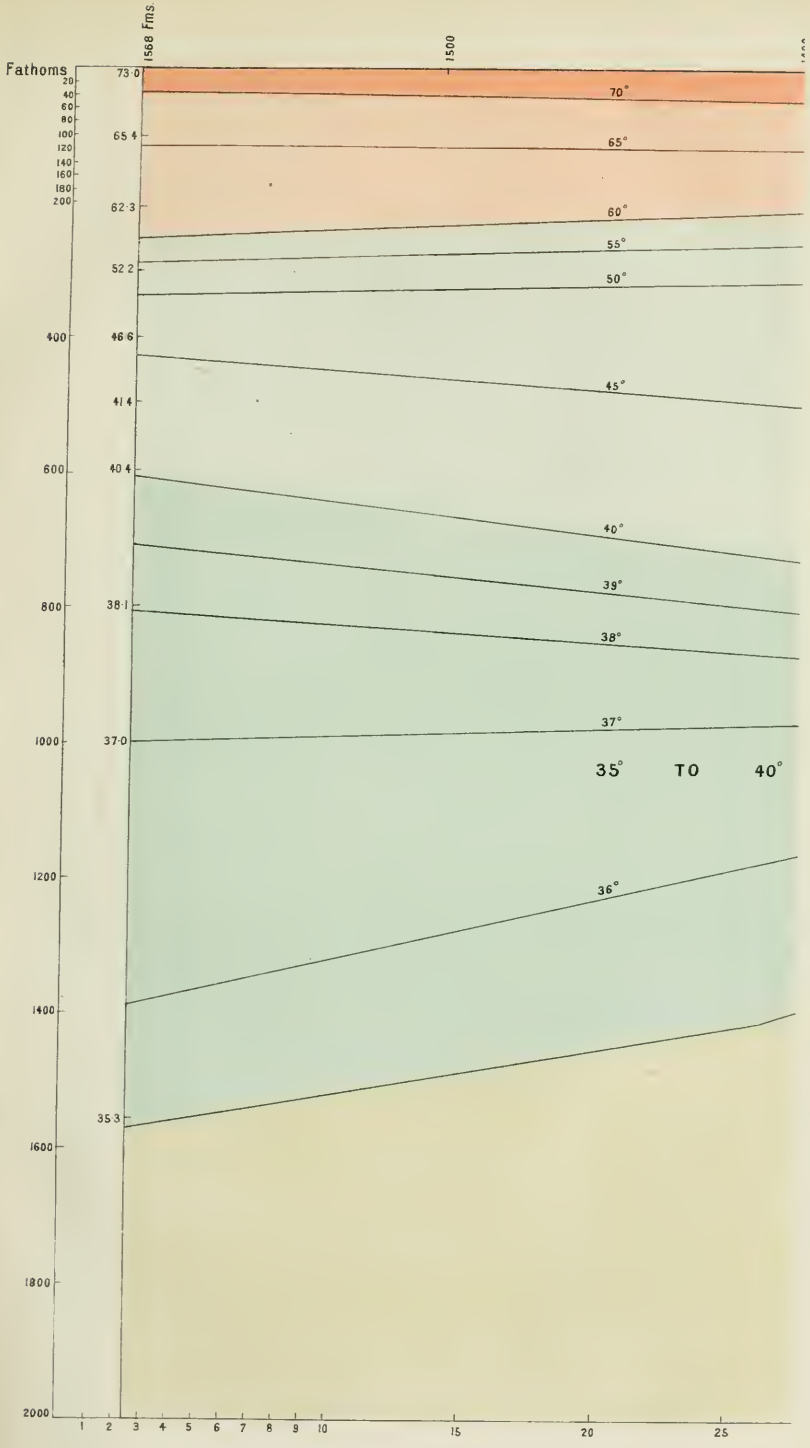
Fine Washings [19·4%], amorphous clayey matter and minute mineral particles.

MAP SHOWING THE DEPTH, PTEROPOD AND GLOBIGERINA OOZES AROUND THE BALFOUR SHOAL



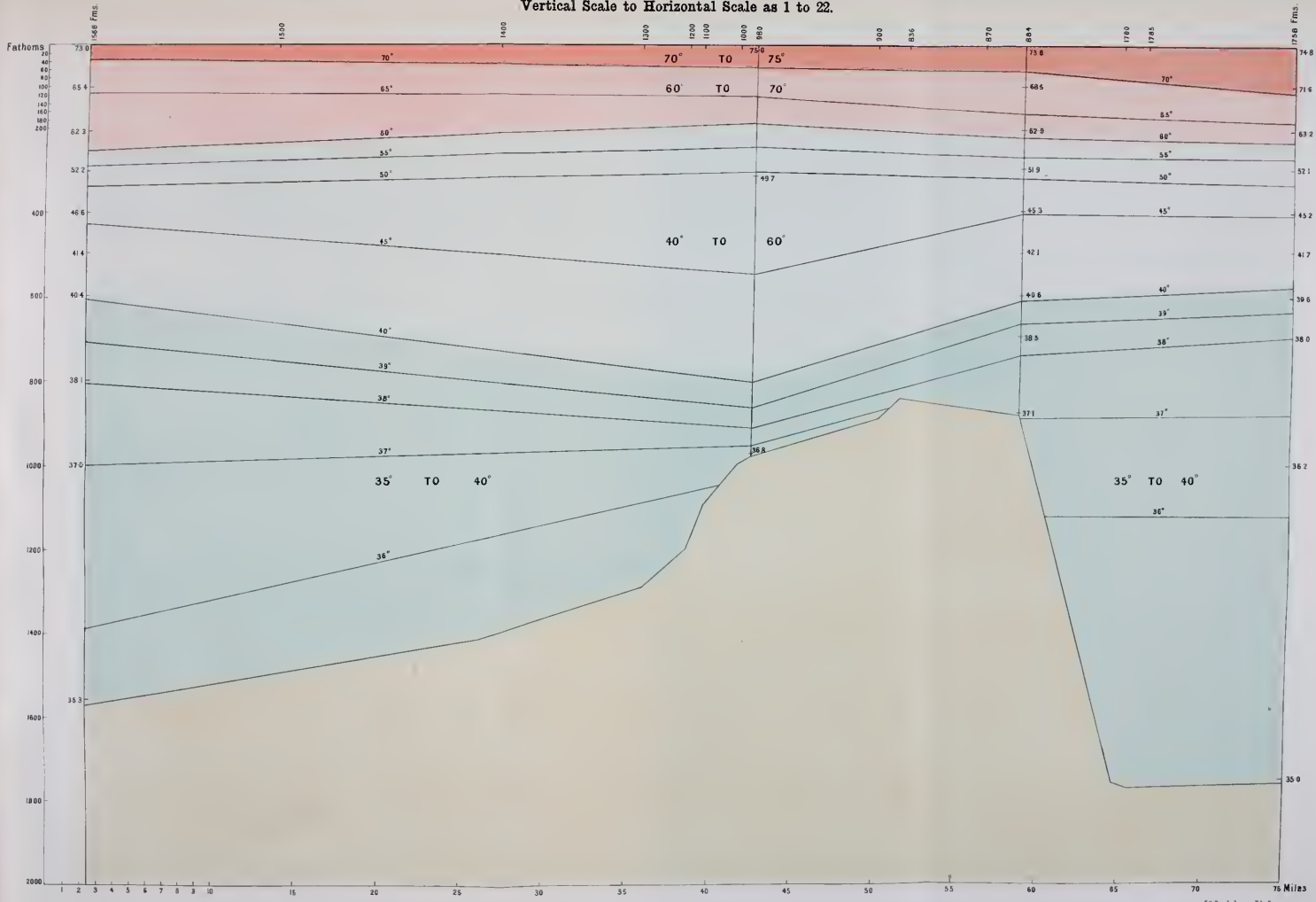
Pteropod Ooze Deposits *occur inside 1000 Fathom Line where depths are shown in shades of Green*
Globigerina Ooze Deposits *occur outside 1000 Fathom Line where depths are shown in shades of Blue & Purple*

SECTION ACROSS THE BALFOUR



SECTION ACROSS THE BALFOUR SHOAL SHOWING THE TEMPERATURES TAKEN 10th TO 12th AUGUST 1894.

Vertical Scale to Horizontal Scale as 1 to 22.



Scottish Geographical Magazine, 1897